A STUDY OF SOIL AND DURICRUST MODELS FOR MARS.

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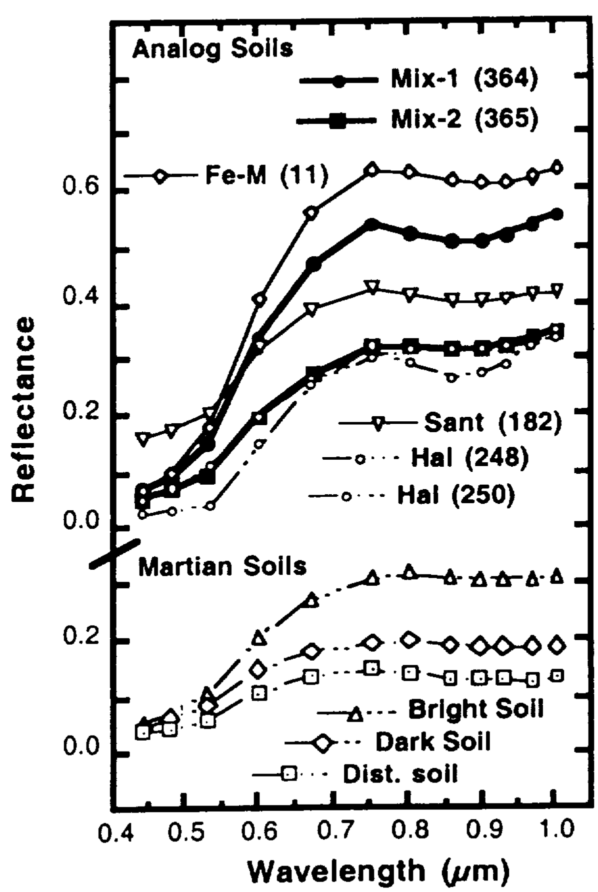
Abstract: This project includes analysis of the Mars Pathfinder soil data (spectral, chemical and magnetic) together with analog materials and the products of laboratory alteration experiments in order to describe possible mechanisms for the formation of soil, duricrust and rock coatings on Mars. Soil analog mixtures have been prepared, characterized and tested through wet/dry cycling experiments for changes in binding and spectroscopic properties that are related to what could be expected for duricrusts on Mars. The smectite-based mixture exhibited significantly greater changes (1) in its binding properties throughout the wet/dry cycling experiments than did the palagonite-based mixture, and (2) in its spectral properties following grinding and resieving of the hardened material than did the palagonite-based mixture.

Introduction: Spectral analyses of laboratory soil analog materials and several soil units measured by the Imager for Mars Pathfinder (IMP) showed that there are specific differences in the soils observed by Pathfinder that are attributed to differences in mineralogy and composition of the soils [e.g. 1, 2]. Specifically, many of the soils are characterized by a smooth upward slope from 0.5 to 0.7 μm and a broad maximum near 0.75 μm. Some soil units have a stronger shoulder feature near 0.6 μm and some exhibit a weak, broad band near 0.9 μm. Variations in the chemical abundances of these soils indicate a good correlation of wt.% SO_3 with the 0.75/0.44 μm band ratios [3]. This suggests that the ferric mineral(s) responsible for the reflectance maximum near 0.75 μm is(are) correlated with sulfates in the soils. Ratios of numerous spectral parameters have been performed in this study and by others. A summary of many useful spectral ratios for the IMP soil spectra is given by [2]. The initial comprehensive analyses of the rocks [4] and soils [2] observed by Mars Pathfinder (MPF) show that there are compositional differences among both the rocks and soils, and that characterization of their mineralogies from the MPF data is non-trivial.

A model was developed that describes potential mechanisms of rock coating and duricrust formation on Mars [5]. This model states (1) that the ~2 μm sized "dust" particles suspended in the atmosphere on Mars are compositionally similar to the "soil" covering the surface of rocks and the ground in between rocks, (2) that physical processes (e.g. wind, dust devils) primarily govern distribution, aggregation and disaggregation of the dust, soil and dust layers on rocks, and (3) that chemical processes (e.g. chemical reactions of the sulfates with the ferric oxide and silicate surfaces in the presence of water and/or redox reactions of Fe^{2+}/Fe^{3+}) are primarily responsible for the formation of rock coatings and duricrust and that once formed, these chemical layers cannot be simply disaggregated by the wind.

Initial spectral analyses of the Pathfinder soils and lab analog materials showed that the IMP soils are similar in spectral character to samples containing nanophase (np), microcrystalline and poorly crystalline iron oxide/oxyhydroxide (FeOx) species and silicate minerals [1, 5]. The IMP bright soils are spectrally similar to np-FeOx-silicate aggregates of 1-2 μm sized particles. Similar aggregate samples containing the np sulfate mineral schwertmannite as well are similar in spectral shape to the disturbed soils. However, these synthetic aggregate soils are significantly brighter than soils on Mars.

Figure 1. Reflectance spectra of the new soil mixtures, their endmember components, and Martian soils (from Yingst et al. [6]).



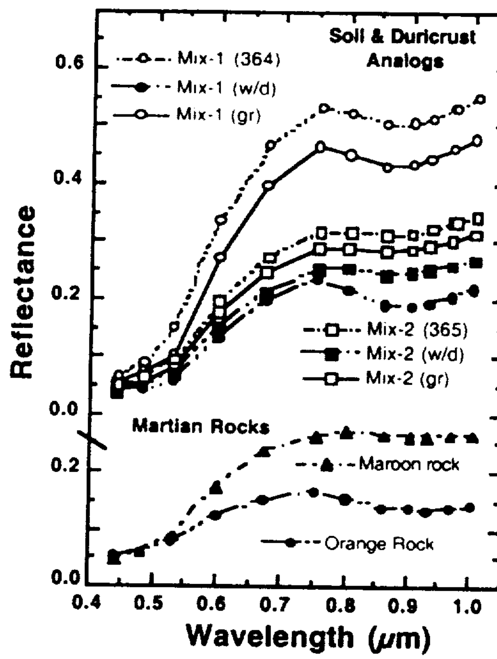
Soil Mixtures: Two soil analog mixtures were prepared that are a combination of synthetic and natural materials. Each sample contains 10 wt.% magnesium sulfate and 10 wt.% of the <45 μm size fraction of two different sulfate-bearing soils formed through hydrothermal alteration. The dominant phase (70 wt.%) in one sample is a synthetic material composed of <45 μm ferrihydrite-montmorillonite-aggregates of smaller particles [7] and the dominant phase in the other sample is the <45 μm fraction of a palagonitic (altered glass, np FeOx and silicates) soil from the Haleakala basin on Maui [8]. Both of these new mixtures exhibit magnetic properties similar to what was observed by MPF for the soils on Mars (R.V. Morris, pers. comm.). The goal in designing these two samples was not to exactly recreate the soil chemistry measured by MPF, but rather to prepare analog materials that are, in general, consistent with the chemical, magnetic and spectroscopic properties of the Martian soil to be used in experiments testing the feasibility of soil alteration reactions on Mars.

Re-sample lab spectra of the two new soil mixtures (364 and 365) and their endmembers are shown in Fig. 1. The character of the sulfate-bearing Santorini soil (182) exhibits the stronger curvature (0.6-0.67-0.75 μm) of the disturbed soils shown in Fig. 1. Sample Mix-1 (364) is darker than its dominant endmember (11) and both the reflectance maximum and minimum are shifted towards shorter wavelengths. Sample Mix-2 (365) is less noticeably changed from its dominant endmember (248).

Duricrust Experiments: Preliminary wet/dry cycling experiments were performed on four samples: the two new mixtures described in Task 1 and each of the dominant endmembers for the mixtures. One drop of distilled water was added to each of the four samples, followed by drying in air. Repeated wet/dry cycles were performed including drying in a desiccator and drying by heating to 50°C for 1 hour. The pair of smectite-bearing samples exhibited swelling and cracking through the hydration/dehydration as expected for smectites. Little difference was observed due to the addition of a sulfate component for this sample pair. For the palagonitic soil samples the presence of sulfates produced changes in the sample behavior as a function of hydration and dehydration. The palagonitic soil sample showed a small amount of cracking and bubble formation, while the palagonitic soil plus sulfates mixture exhibited more cracking and bubbling, as well as separation of some of the sulfate material from the sample mixture.

Re-sample lab spectra of the initial (powdered, <125 μm) new soil mixtures, hardened "duricrusted" material from the wet/dry cycling experiments, and re-ground and sieved "fluffy" material for the two mixtures are shown in Fig. 2 along with spectra of two rocks near the Mars Pathfinder lander. The Maroon and Orange rock spectra were selected for comparison here because they exhibit stronger spectral features than the more typical Black rock [9]. The unique spectral character of the Maroon and Orange rocks have been attributed to the presence of coatings [10]. The wet-dry cycling experiments had a much more pronounced effect on the spectral character of the smectite-based sample (Mix-1) than they did on the palagonite-based sample (Mix-2).

Figure 2. Reflectance spectra of the new soil mixtures as the initial powder (<125 μm), as "duricrusted" (w/d) soil mixtures, and as re-ground (gr) and resieved soil mixtures (<125 μm), and the coated martian rocks "Maroon" and "Orange" from MPF (from Barnouin-Jha et al. [10] and Murchie et al. [9]).



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